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ROSAT OBSERVATIONS OF SOLAR-TYPE G STARS

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ABSTRACT We present ROSAT All-Sky Survey X-ray observations of three apparently solar-type main-sequence stars with extremely active coronae. These stars have been reported to be microwave sources. They comprise a Pleiades-age solar analog that exhibits strong evidence of rotational modulation, a flaring star, and a very old star leaving the main sequence. Observations of coronae of such stars may be important for an understanding of the evolution of solar activity.

OBSERVATIONS OF CORONAE OF SOLAR-TYPE STARS

We have investigated the behavior of a selected sample of solar-like main-sequence (MS) G stars both in X-rays and microwaves. Solar-like stars are thought to rapidly lose much of their initial angular momentum early in their lifetimes; therefore nonthermal, magnetic microwave activity and very hot ($\sim 10^7$ K) coronae are thought to become increasingly less pronounced with age in these stars.

¿From the ROSAT X-ray Survey, we extracted count rates of a sample of the X-ray brightest MS G stars. Based on this information, we conducted a small VLA 8.5 GHz microwave survey (the results are reported in Güdel et al. 1993); five stars were detected. Interestingly, their ages are spread over the complete range of possible ages of MS G stars. We inspected their X-ray data to study variability and other characteristics of their coronae. Here, we present results of three datasets. Each ROSAT lightcurve is composed of ~30 second snapshots separated by about 96 minutes – the satellite's orbital period.

HD 129333 – A Young Solar Analog

HD 129333 is a Pleiades-age ($\sim$ 70 Myr) very active dG0e star (Soderblom & Clements 1987) with a period $P_{\rm rot}$ of only 2.7 days (see Elias & Dorren 1990). It is thus not too surprising to find this star at a very high X-ray luminosity of $\log L_X \approx 29.9$ (L_X in ergs s^{-1}; assumed distance 31 pc). ROSAT obtained an exceptionally good temporal coverage over 5.2 days, i.e. ~two rotations, because

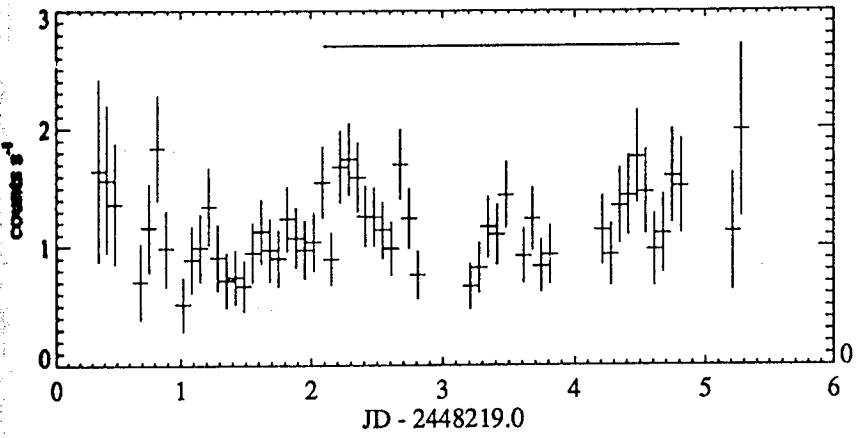

FIGURE I Lightcurve of HD 129333 from the ROSAT All-Sky Survey. Notice slow variations which are compatible with the length of the rotation period of $\sim$ 2.7 days (bar).

HD129333 is located near the northern ecliptic pole.

The lightcurve shows a conspicuous level of variability (Fig. 1). Individual peaks may be interpreted as X-ray flares similar to those frequently observed on M dwarfs. However, the timescales would be extremely long, viz. of the order of a day. A more appealing alternative is modulation of the flux with the star's rotation, indicating that the emitting regions are inhomogeneously spread over the stellar surface. Indeed, the overall variation is compatible with a period close to $P_{\rm rot}$ (a statistical analysis is in progress). This makes it very unlikely that the X-ray emission comes from a cool companion. A distant companion with $P_{\rm orb} \sim 12$ yr has in fact been announced recently (Duquennoy & Mayor 1991), although its characteristics remain unknown.

Gliese 97: A Flare from a G Star?

Gliese 97 (spectral type G1V) has been reported to be a middle-aged bona fide analog of the Sun (Soderblom 1983), with $v\sin i \approx 4$ km s^{-1}. Nevertheless, it shows a surprisingly high level of coronal X-ray emission, with $\log L_X \approx 29$. The lightcurve exhibits, above constant "quiescent" emission, a strong X-ray flare (Fig. 2).

Lacking time resolution (thus having a lower limit for the flare peak and an upper limit for the duration), let us assume a triangular shape defined by the peak and its nearest data points (half-power duration $\approx$ 100 minutes, which is typical for large solar flares); with this, a rough estimate for the total emitted energy is $1.5 \cdot 10^{33}$ ergs, which exceeds the strongest solar flares by an order of magnitude. If this flare originated from the optical G star rather than from an unseen cooler companion, it is one of very few large X-ray flares reported from G stars; EXOSAT observations of π^1 UMa by Landini et al. (1986) revealed a flare with a similar total energy emitted in X-rays. We emphasize the importance of investigating whether Gl 97 has a cooler companion with a very active corona.

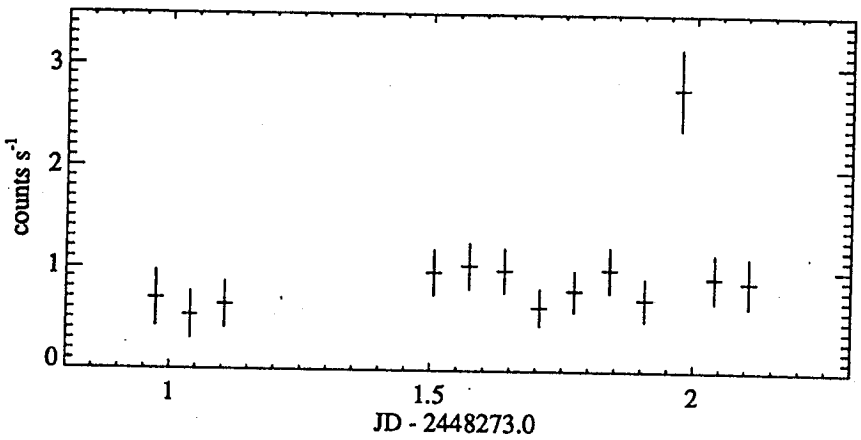

FIGURE II Lightcurve of Gl 97 from the ROSAT All-Sky Survey.

HR 9107: A Very Old but Active Star

This is a surprise detection both in X-rays and microwaves. HR 9107 is a metal-deficient, high space velocity, old-disk population MS star of the "solar" spectral type G2V, moving toward the subgiant class (Deliyannis et al. 1990).

We found $\log L_X \approx 29.6$. It is puzzling that a star which is much older than the Sun supports strong X-rays and microwaves at a level orders of magnitude brighter than even the strongest solar flares ($\log L_X \approx 28$). This detection would remain puzzling even if the coronal emission originated from an undetected cooler companion, since stars at this age, i.e. ~ 10 Gyr, are not expected to support very active coronae. The nature of HR 9107 deserves to be investigated more closely with regard to possible undetected companions and the activity signatures from other levels of the stellar atmosphere.

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